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Agricultural Research Institute, Pusa

DISEASES OF RICE

BY

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DISEASES OF RICE.

I.—AN EELWORM DISEASE OF RICE.

1. Introductory.

In October, 1908, Babu Anukul Chandra Ray, an Honorary correspondent of the Eastern Bengal Department of Agriculture, reported the prevalence of a disease of rice, of which little had been heard before, in the districts of Noakhali and Tippera at the head of the Bay of Bengal. The disease was locally known as "Ufra," from "upara" meaning "above", the cultivators believing that atmospheric conditions and the curious natural phenomenon, known as "Barisal guns," heard at the head of the Bay, produced the diseased condition of the crop.

Mr. C. W. Mason, Supernumerary Entomologist at Pusa, visited Tippera shortly afterwards, to investigate the disease. He reported [1] that it was apparently not caused by insect attack and described its characters as follows. The first appearance is at the end of the rains. The ends of the leaves of plants affected turn brown; afterwards the ear, which is just forming, and then the whole plant, dies off. The attack commences in the same field every year, in small patches which spread wider and wider as the season advances. Many plants, however, do not die immediately, but merely look stunted in growth and produce little or no grain. The leaf is, while green, if anything a darker green than normal, and certainly not suffering from drought, which would make the leaf pale. The disease occurs on dry land and wet flooded lands alike, and does not affect any special varieties of paddy; as far as is known all are liable to it. Often one small field may be affected in the middle of large areas of paddy, none of the surrounding plots being attacked, though the land is apparently cultivated at the same time, manured and treated in the same way as surrounding plots.

Mr. Mason's specimens were examined by me on his return to Pusa and the conclusion arrived at was that the disease was similar to the well-known but obscure condition known as "brusone," which occurs in most rice-growing countries.

[1] Leaflet, Department of Agriculture, Eastern Bengal and Assam, No. 1 of 1909.

Further reports received in 1910, threw doubt on the above conclusions and suggested that the whole of the damage might be caused by insects, a number of which were known to cause losses to paddy cultivation in Lower Bengal. In 1911 the disease was severe. The Honorary correspondent at Chaumuhani, Noakhali District, stated that the extent to which paddy plants were dying in the neighbourhood was so great that the cultivating classes were on the verge of utter ruin, and unable to pay for seed, rent or the cultivation of their lands. Another correspondent wrote that he was a poor man, cultivating a little land, out of which three bighas, containing paddy, had been entirely destroyed by "ufra" for the last three or four years; "if the disease continues" he concluded "I shall be undone."

Accordingly arrangements were made by the writer with Mr. T. Bainbrigge Fletcher, Officiating Imperial Entomologist, for a combined entomological and mycological investigation. We visited Chaumuhani in December 1911, accompanied by Mr. A. G. Birt, Deputy Director of Agriculture, Eastern Bengal and Assam, whose local knowledge of the Province proved very useful. Mr. Fletcher found that borers of the genera *Schoenobius*, *Chilo* and *Nonagria* were present abundantly and must have accounted for a very large amount of damage in the aggregate. He agreed with me, however, in holding that they were not responsible for the very definite group of symptoms of the disease to which the bulk of the losses were due and that this was probably associated with the presence of large numbers of a microscopic eelworm, of the parasitic and semi-parasitic genus *Tylenchus*, which I discovered in every typical case of ufra.

My preliminary report, the result of investigations carried out during this tour and immediately after my return to Pusa, was communicated to the International Institute of Agriculture, Rome, by the Director of Agriculture, Bengal, under an arrangement by which early intimation of the occurrence of any new disease of an important crop is given to the Institute for publication.[1] Subsequent work has confirmed the earlier conclusions, and it is possible now to give a more connected account of the disease and of the organism associated with it.

In the Districts affected, which according to present information comprise Noakhali, Tippera and parts of Dacca, paddy is the staple crop, occupying over 70 per cent of the cultivated area. As is usual in the

[1] Bulletin of the Bureau of Agricultural Intelligence and of Plant-diseases, 3rd year, No. 7. July, 1912, p. 1661.

Eastern Delta Districts of Bengal, there are three main crops of paddy in the year, the "aus" the "aman" and the "boro," each subdivided again into several varieties.

The aus is sown in this area from the middle of February onward to the beginning of May, depending to some extent on the character of the land and on the season, and is harvested from July to September. It is usually grown on land slightly higher than the rest of the paddy fields, a few inches being often enough, the object being to select land which will not get deeply submerged in the early part of the monsoon. In much of Noakhali, however, aus is grown on low lands (but not the very lowest), mixed with aman and sown as early as possible, each crop being harvested as it ripens; early maturing varieties of aus, harvested in July or the first half of August, being selected for these low lands. Aus is almost always broadcasted, though a little is transplanted. In Noakhali the area under paddy was returned as 965,000 acres[1] in 1908-9 and the estimated outturn was 335,000 tons of clean rice. About one-third of this area was under aus. In Tippera, in the same year the area was 1,034,000 acres, of which 320,000 acres were under aus, and the average outturn for the 5 years ending 1907-8 was 400,000 tons. The aus yields less than the aman and the grain is inferior to the better class of aman.

The aman may be divided into two main classes, the long-stemmed or deep water rices, which form the bulk of the crop in this area and are sown broadcast alone, or (especially in Noakhali) mixed with aus, in March to the beginning of May; and the transplanted or short-stemmed aman ("sail" or "roa"), sown in seed-beds in May to July and transplanted in August and September. Both classes are harvested in November and December. The deep water varieties are coarse and withstand flooding to a remarkable extent, being said to grow as much as 9 inches in 24 hours and to reach a length sometimes of 20 feet. When grown mixed with aus they are known as "bajal", the mixture being half and half, or more often one-quarter aman to three-quarters aus, in Noakhali. The deep water rices are grown in the lowest lands and in some places, where the inundation is early, have to be sown in February. They keep pace with the rise of water and at harvest only the ears and 1 to 1½ feet of stalk are cut, the rest, often many feet in length, being left as stubble. A cold weather crop of pulses, such as Khesari (*Lathyrus sativus*), is sometimes sown on top of the paddy just before harvest.

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[1] Land from which two crops are taken is counted twice.

Transplanted aman is grown either as a single crop or as a first crop followed by cold weather pulses or as a second crop following aus paddy or jute. The best varieties are grown on the higher lands. In the western part of Noakhali little transplanted paddy was grown until recent years, according to local information, but there is now about 20 per cent. of this class in the neighbourhood of Chaumuhani. This is partly due to the extension of jute cultivation, the transplanted paddy being taken as a second crop, partly to the ravages of ufra on the broadcasted crop. The seed is grown in seed-beds until the jute or unmixed aus is harvested, then transplanted into the higher fields after a few ploughings at the end of August or in September.

Boro paddy is of much less importance than the other two, being practically unknown in Noakhali and occupying only a comparatively small area in the other Districts. It is grown on muddy land along the rivers and creeks. It is generally transplanted, but sometimes broadcasted on the mud flats. When transplanted the seed is sown in late October or November, and planted out, usually without any previous preparation of the land, in December or January. Irrigation is required, except where tidal water reaches the fields. Harvest is in April or May. The yield is heavy but the grain is coarse. Broadcasted boro is sown in December or January and harvested at the same time as the transplanted.

It will thus be seen that the chief paddy harvest is in November and December. The broadcasted aman, including the bajal, leaves a quantity of coarse stubble in a matted mass on the still damp fields. This stubble is almost worthless as cattle fodder but the cattle are often turned loose to pick up what they can of weeds or rotting stubble in the fields. In the northern part of the district under consideration the fields are sometimes raked clean and the débris burned, but this is certainly rare in Western Noakhali. Ploughing is said to be sometimes done immediately after harvest but this again is unusual in Noakhali, where the first ploughing of the low lands appears to be usually in February after a fall of rain. The early showers in February and March are extremely important in softening the heavy clay of the land subject to inundation sufficiently to admit of ploughing with the inferior work cattle of the district. The fields which grow cold weather pulses, sown in the mud before the paddy harvest, are not worked until these crops are harvested. What remains of the stubble is often collected for fuel before ploughing begins. Five or six ploughings are given in February and March or later in the higher lands. The tillage operations naturally vary in the different qualities of

PLATE I.

UFRA AND BUNT OF RICE.

land and for the different classes of paddy it is intended to grow, but as far as I can ascertain, the low land, on which deep water aman and bajal are grown, gets less cultivation than the others and may even be under paddy for 9 or 10 months of the year, and have stubble on them for a month or more after harvest.

2. Description of the disease.

Ufra has been found in aus and aman but has not as yet been reported in boro paddy. In Noakhali the first attack is found in the aus crop, both that grown alone (not common) and that in the bajal mixture, about the end of June when the crop is beginning to come into ear. It occurs at first in patches which do not spread with great rapidity; though the loss in a given patch may be complete, the total amount of damage to the aus crop is not large, as harvest occurs before the attack is widespread. At the time of the severest aus attack, early in August, the broadcasted aman is still less than half grown and shows no sign of ears. Careful examination indicates that the latter crop has, however, the early symptoms of disease even at this stage. It is, indeed, probable that signs of infection could be detected in the aus before June, but an opportunity has not occurred for examination in the early stages of its growth. In the broadcasted aman, whether alone or mixed with aus, whole fields may be clearly diseased in late August and September. It is probable that there is no real difference in susceptibility between the aus and the aman but that there is a progressive multiplication of the cause of the disease, insufficient to do much harm to the former but capable of great damage to the latter, owing to its longer period of growth.

The earliest stage which I have collected was in aman paddy at the end of July. As already noted I have not seen the early stages in aus, but there is no reason to suppose that they differ. The case referred to was a field of unmixed broadcasted aman paddy in about the fourth month of growth, which the owner said had what he called "pata" (leaf) ufra and would ultimately be all lost. The plants showed little to distinguish them from the normal. The tips of the leaves were however withering and some of the shoots were pale and flaccid at the top, where they consisted of inrolled leaf blades, of the ordinary type of leaf-bud of grasses. Here and there were brown stains on the leaves and sheaths. On removing the latter the inner layers of the bud were found slightly wrinkled and sometimes faintly stained brown. The stem was unaltered in the

lower part but with a few brownish stains in the upper internodes. Some plants were taken from this field and transplanted on the Dacca Farm. A month later eight out of fifteen clumps thus transplanted had died. Three weeks later five more were dying. The outer leaves withered completely and the shoots and inner leaves gradually dried up. Brown marks were found on the inner layers of the buds and well-marked brown lesions on the stems, usually just above one of the upper nodes. The other two clumps came into ear and were dug up after about two months, at harvest time, nearly four months after transplantation. Some of the ears were normal, others with light grain. The inner sheaths had scattered brown patches and some of the stems had brown lesions. In these two clumps the attack was mild, and had not developed sufficiently at the time of harvest to do much damage. The field from which the plants were taken developed a severe attack as predicted by the owner. Transplanting after the attack had commenced had apparently, in this case, the effect of hastening the death of the plants, as the ordinary course of the disease is more gradual and the majority of the affected plants, if undisturbed, come into ear, though the ear may fail to emerge from its sheath and the grain does not mature properly.

The following description of the later stages of the disease applies equally to aus and aman and the cases may be seen at any time during the month prior to harvest. The plants are often stunted, the outer leaves sometimes withered, sometimes unaltered, the sheaths with brown stains and the stem with very characteristic lesions just above one or more of the upper nodes. The stem lesions are almost always confined to the half inch or so just above the last node which bears a leaf (leaving out the node bearing the peduncle of the ear which has no leaf) and sometimes also the node next below. At this point the stalk is of a deep brown or black colour, flaccid, and shrunken, sometimes to little more than the thickness of a thread (Plate 1, fig. 1). The discolouration may be, in mild cases, on one side of the stem only, but usually extends all round. Scattered small brown lesions may be found elsewhere on the stem in some cases. The peduncle may appear normal or may be similarly discoloured and shrunken. According as the ear remains enclosed in the sheath of the top leaf or emerges, the cultivators distinguish two types of the disease as "thor" (swollen) or "pucca" (ripe) ufra. In "thor" ufra the upper part of the stalk appears to be swollen into a spindle-shaped swelling, which in reality consists of the ear, entirely enclosed in its sheath (Plate 1, fig. 4). The enclosing sheath may be

wholly withered and the blade of this leaf (the "flag") is so usually, but in the early stages the sheath dries up only along the overlapping margins. The withering may extend either from the base of the sheath upwards or from the flag downwards. The median part of the sheath remains green for a time but soon shows definite brown stains, which are amongst the most characteristic symptoms of the disease (Plate 1, figs. 3 and 4). These stains may be diffused and scattered or may cover a large part of the sheath continuously. They often show zones of lighter and darker colour, occasionally arranged in concentric or parallel bands. The base of the sheath is usually stained uniformly brown where it covers the stem lesion above the last node. On removing the sheath the arrested ear is found to contain mostly unfertilised flowers or shrivelled grain and frequently the whole ear is mouldy and covered with saprophytic fungi. In "pucca" ufra the ears escape from the sheath wholly or in part, all stages of transition from "thor" ufra being found. The attack in these cases is often most marked in the peduncle itself and probably reaches its maximum intensity at a later period in the development of the plant than in "thor" ufra. The sheath of the upper leaf is usually withered and brown and may imprison the upper part of the ear while the lower escapes, thus giving rise to twisted and distorted heads. The glumes usually contain no grain in the lower part of the ear, the upper being also empty in some cases but more usually with partially developed or sometimes even perfectly normal grain.

It is possible to find plants at the margin of spreading patches of disease, especially in aus paddy, showing some shoots with normal ears, others with different stages of "thor" and "pucca" ufra. Towards the centre of such patches, where the disease has been longer in progress, every ear is generally affected. Fields were seen where the loss did not exceed ten per cent and others where it was practically complete. In aman paddy the intensity is generally high, as the long growth period allows the parasite to multiply greatly.

3. Cause of the disease.

It is certain that ufra is not caused by insect attack. At the time of harvesting the winter paddy, numerous insect pests are found in the crop. None of these cause symptoms resembling those described above, especially the diseased areas just above the stem joints, unaccompanied by any obvious wound, and the brown spots on the ear sheath. In the attack on

early rice and the early stages of the attack on late rice, hundreds of cases can be easily found where there is no trace of insect damage.

Parasitic fungi are more difficult to exclude. A considerable number of fungi are known on rice, a recent Japanese publication [1] enumerating some eighty species, of which perhaps more than half are parasitic. Only one of these causes symptoms which resemble some of those of ufra. This is *Piricularia Oryzae* Cav., a fungus which is believed to cause the disease known as "brusone" in Italy and "blast" in America, and which occurs in India as well as in most other countries where rice is grown. It is by no means certain, however, that brusone is caused by *Piricularia* [2] and it undoubtedly does not cause ufra. Apart from the fact that the most careful examination, both microscopic and by cultural methods, has failed to reveal any trace of this fungus in many cases of typical ufra, especially in the aus and early aman attacks, the symptoms caused by *Piricularia* differ in important characters. The leaves are more severely affected, brown or reddish spots developing at the base of the sheath and where the blade joins the sheath, and these spread so as usually to kill the leaf. The stem lesion is, as in ufra, in the neighbourhood of the upper nodes but the node itself is involved and even the stem just below it, and open wounds occur which eat through the stem tissues, often causing the head to fall off.[3] The same occurs (though without the open wounds) when the base of the peduncle is affected. At these lesions the fungus is found readily. In the variety of the disease, said not to be associated with *Piricularia* in Italy, the roots are discoloured and rotted at an early stage and the leaves become reddened and wither, before the stem lesions at or near the nodes appear. The latter may, indeed, be altogether absent. In the early stage of ufra the roots are not altered and the leaf symptoms are not easily recognised. Rice plants attacked by *Piricularia* in India have prominent reddish-brown spots, with a pale centre, on the leaves, similar to what has been described from Japan.[4] These are quite unlike anything which has been seen in ufra. The stem lesions in the two cases are not unlike but those caused

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[1] Miyake, I. Studien ueber die Pilze der Reispflanze in Japan. Journ. Coll. of Agric. Imp. Univ. Tokyo, II, 1910, p. 237.

[2] See especially Brizi, U. Richerche sulla Malattia del Riso detta "Brusone." Annuario d. Ist. Agrar. A Ponti, 1905, and subsequent papers in the same Journal.

[3] Metcalf, H. A. Preliminary Report on the Blast of Rice. South Carolina Agric. Expt. Stat. Bull. 121, 1906.

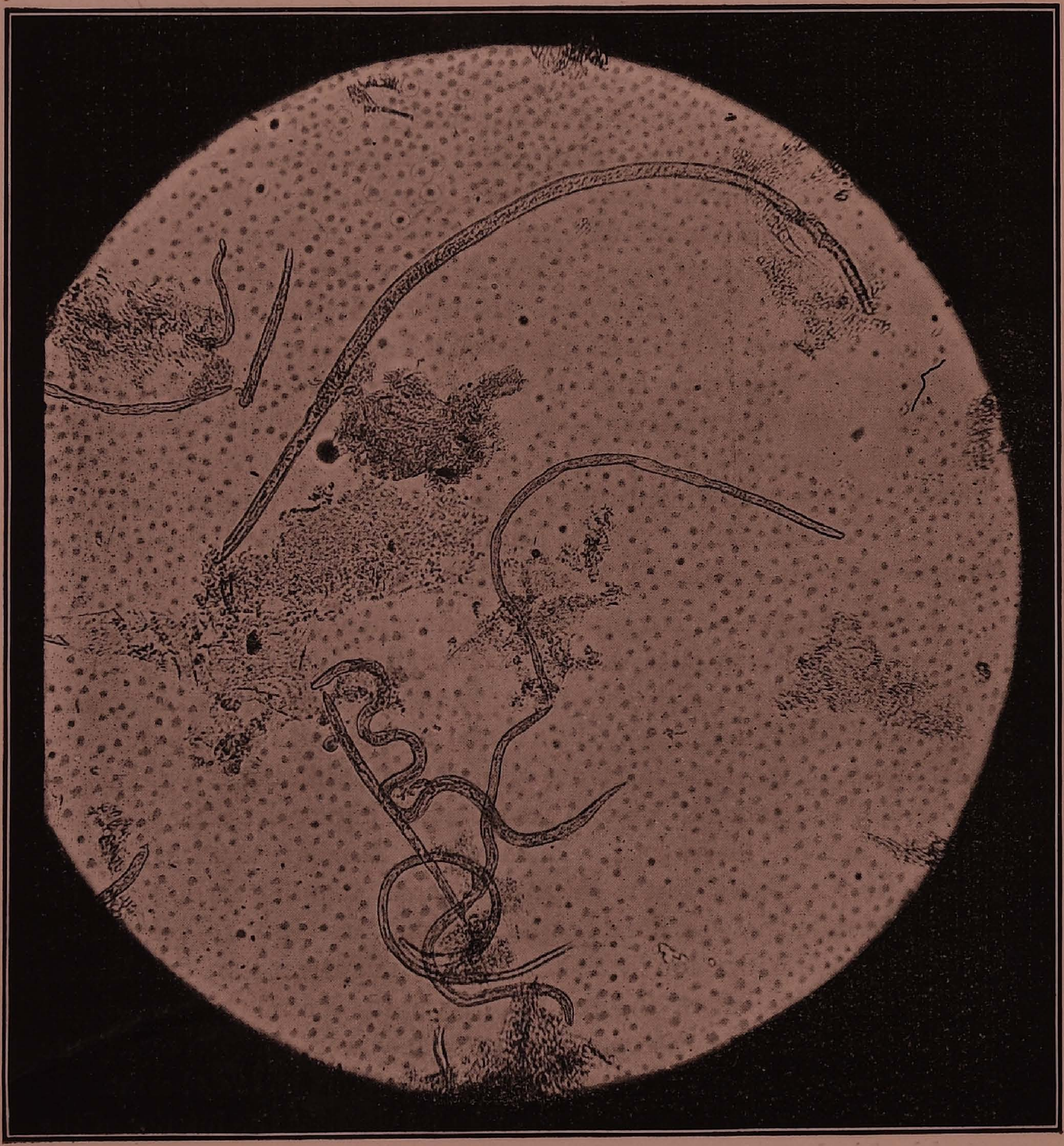
[4] Kawakami, T. La Maladie "Imotsi" du Riz. Bull, Soc. Agron. de Sapporo, II, 1901. (Ref. in Bot. Centralbl. XC, 1902, p. 301.)

by *Piricularia* are more diffuse and lead to greater destruction of the tissues than those present in ufra.

Bacteria have been stated to cause diseases of rice in Italy and Japan. An attempt was therefore made to determine whether any pathogenic bacteria were present in ufra. For this purpose the lesions on the stem were selected as being the most likely place to contain them. The root system does not appear to be involved in any way in the earlier stages of the disease. The leaf symptoms clearly do not account for the major part of the damage, which is obviously due to the death of the stem at the specified points above the upper nodes. Accordingly four clean fresh cases of "thor" ufra were selected and the sheath carefully removed, exposing the shrunken discoloured stem lesion. About ¼ inch of this was cut from each case with sterile scissors, washed thoroughly in several changes of boiled water, dipped into absolute alcohol for a few seconds, the alcohol flamed off, and the pieces dropped into prepared culture tubes of nutrient agar. Two of the tubes remained sterile and gave no growth. The other two gave bacterial growths, from which three distinct types of bacteria were isolated and grown in pure culture. With each of these, ten plants of rice, ten weeks old, were inoculated. The inoculations were made by mixing some of the culture with distilled water and puncturing the shoot about one-third of its length from the ground with a sterilised needle dipped in the culture. Several punctures were made in each shoot. All the plants remained perfectly healthy and matured their grain about 3½ months later.

No other organism having been found regularly associated with the disease, work was continued with the eelworms which, as already stated, were found on all the diseased plants. In the earliest stages of "pata" ufra, from the field mentioned on p. 5 above, they were found only in the inner layers of the leaf-bud at the apex of the shoot, both in the neighbourhood of the growing point of the stem and higher up, where the bud consists of inrolled leaves only. In the plants from the same field transplanted in the Dacca Farm, they were found, two months later, in the same position but in considerably greater numbers. In these plants they were also found under the leaf sheaths of the upper nodes. In all cases of ufra examined before the ears had developed, the eelworm was found in these localities, though sometimes also a few were detected on minute scattered stem lesions and on small brown spots on the leaf sheaths. It is clear, however, that it tends to make its way into the interior of the apical leaf-bud as soon as possible.

In "thor" ufra the worms congregate at the seat of the lesions on the stem, above the upper nodes and at the base of the peduncle. They may also be found higher up the ear on the branches of the inflorescence. The lower empty glumes also usually contain some, and stray ones may be found in other localities at the upper part of the plant. Very much the same conditions may be found in "pucca" ufra but the grains more frequently contain worms (Text fig. 1), which lie within the glumes but



TEXT FIGURE 1.

outside the grain proper, when one is developed. Very large numbers of worms have been found in some cases on the very young inflorescence, while this is still buried in the apical bud (Plate II, fig. 2). In other cases they have formed an almost continuous coating, comprising hundreds of individuals, on the discoloured shrunken stem just above the upper node.

To determine if these worms were capable of producing the disease, two series of experiments were carried out in 1912, at Dacca and Pusa respectively.

For the Dacca experiments a plot of recently transplanted aman paddy was selected in the first week of August, the plants standing in about 3 inches of water, above which they projected about a foot. A single shoot was inoculated in each of twenty different, but adjacent, clumps. A piece of peduncle or culm with characteristic lesions and bearing eelworms, cut from cases of "thor" ufra of aus paddy brought from Noakhali, was inserted beneath the leaf sheath of one of the upper leaves and fixed in position by a loop of string. The first indication of disease was observed in the inoculated plants about the middle of September.[1] On the 1st October four clumps from those inoculated were uprooted and sent to Pusa for examination. The shoots were sickly in appearance, the tops pallid or withering, the lower parts still for the most part green. The upper sheaths and some of the leaves bore small brown marks, similar to what had been seen in Noakhali in August. A few worms were found on these spots. On removing the outer sheaths, scattered marks were found on the inner sheaths and the middle layers of the leaf-bud of the shoot, but the worms were still scarce. The inner layers of the bud were examined, down to the apex of the stem. Worms were plentiful here, occurring in all the inner folds of the bud and near the top of the stem. On October 26th, Mr. G. P. Hector, Economic Botanist, Bengal, examined the plot and reported that the remaining inoculated clumps undoubtedly appeared to be in an unhealthy condition as compared with the bulk of the surrounding uninoculated plants, though he was unable to say that they showed any specific symptoms which were not also exhibited by occasional other plants in the field. They appeared stunted, and the stems showed signs of decay and blackening, and the leaves of withering from the tips backwards. Two or three were almost in a dying condition and he doubted if they would reach the flowering stage. In fact they seemed

[1] The Dacca experiments were kept under intermittent observation only.

to be slowly rotting away. At the end of November, my assistant, Mr. S. N. Mitra, visited the plot. Some of the inoculated clumps were dead, others dying. The ears had formed but the grain had failed to develop. The characteristic symptoms of "thor" and "pucca" ufra were found. The non-inoculated clumps in the neighbourhood had also taken the disease, all that were very near showing its symptoms. Two of the inoculated and two of the neighbouring non-inoculated clumps, with characteristic symptoms of ufra, were placed in spirit and brought to Pusa, where I examined them. Large numbers of the eelworm used for the inoculation were found on the inner surface of the upper sheaths, on the stem and in the grains. The plants were undoubtedly suffering from a severe attack of perfectly typical ufra.

A second experiment was made at Dacca on the same day (6-8-12) as the inoculation described above, in a plot separated from the last by a bund, the crop and all the other conditions being similar. The same material was used for inoculation but the pieces of diseased culm and peduncle were placed in the mud and water in contact with the base of the plant, instead of being inserted under an upper sheath. Ten clumps were thus treated. By the middle of September a few clumps showed signs of disease. On October 1st, four clumps were uprooted and sent to Pusa for examination. The symptoms were similar to, but not quite so strongly marked, as those of the first experiment at the same date. The upper sheaths surrounding the apical leaf-bud had brown marks in some cases. A few worms were found on the stem in the upper two or three internodes, which were thin and flaccid. A few were also found in the sheaths of the outer and median layers of the apical bud. In the inner layers large numbers of worms were found as before. Careful examination by sectioning, so as to include the centre of the bud and the growing point of the stem, showed that the worms passed between the folds of the young leaves without actually piercing the tissues and occupied the spaces around, above, and for a short distance below, the growing point, but were unable to reach the latter owing to the tightness of the last folds immediately around it. This no doubt explains why it is that the plants are not usually killed but continue to develop up to the flowering stage. Microscopic brown marks were found towards the apex of the stem and on the bud layers, confined to the superficial tissues only. These were not visible to the naked eye, the organs being merely flaccid and pale. Examined by my assistant at the end of November the remaining clumps of the experiment were found to have a severe

attack of typical ufra, quite similar to the cases in the first experiment. In this plot also the neighbouring plants became infected, the first two clumps, close to those inoculated, having been noticed on October 1st. Even at a considerable distance from the inoculated plants, stray cases of ufra were found, the disease having previously been unknown on the farm. Arrangements were made to destroy the crop and sterilise the soil in the infected plot, as soon as the above observations were completed.

The second series of experiments, carried out at Pusa, was a duplicate of the above. Two small plots were selected and seedlings of local rice, one month old, transplanted into them on July 19th. Ten shoots, in ten different clumps, in one of the plots, were inoculated on August 28th, by inserting within one of the upper sheaths a piece of culm, with the characteristic lesion and containing live worms taken from cases of "thor" ufra of aus paddy, collected at Noakhali on August 3rd. Stalks containing live worms were placed in the water at the base of a few clumps in another corner of the plot. On September 11th, fifteen more shoots were inoculated in the same manner as the ten done on August 28th. The other plot, separated only by a small bund, was kept as a control.

One plant of the earlier batch showed a slight brownish discolouration on the sheath, over the inserted piece of culm, on September 5th. By the 10th the stain was a couple of inches long and quite similar to the sheath stains seen in ufra. A second plant had a smaller brown patch and two or three others were slightly discoloured at the point of inoculation. By October 12th, a number of the inoculated plants in both batches showed brown spots on the sheaths, while none could be seen in the control plot. The ears began to form in the first week of November, and by November 16th unmistakable symptoms of "thor" and "pucca" ufra were visible both in the inoculated clumps and those which had infective matter placed at the base. The controls were still perfectly healthy. Seven clumps containing seven inoculations of the first batch and three of the second were dug up and examined in the laboratory on November 16th. One of the inoculated shoots is figured on Plate I, fig. 3. It is a typical case of "pucca" ufra. Another is shown in fig. 2, with the sheath removed to show the characteristic stem lesion above the last node below the ear. Very great numbers of the worm used for the inoculations were found in this case and in several of the other more severe cases, in some of which they formed an almost continuous coating comprising hundreds of individuals, on the diseased part of the stem. Some of the

shoots had obviously mild attacks and here the stem lesions were less marked and worms occurred chiefly in the lower empty grains. All had, however, much greater numbers than were used in inoculating and all showed typical symptoms of ufra, differing only in degree.

A clump was also examined, on the same day, from those inoculated by placing pieces of diseased stem at the base. One of the shoots was a typical case of "thor" ufra, the others being but little affected. A few other clumps in the plot growing near those inoculated, but not themselves inoculated, had taken the infection, with typical symptoms, and contained large numbers of worms. Practically all the inoculations succeeded but the remaining cases were not examined in detail.

The evidence that ufra is caused by this worm may now be summarised.

The organism belongs to a genus of which several species, notably *Tylenchus tritici* Bauer and *T. dipsaci* Kühn, are known to cause serious diseases of cereals.

It has been found in every case of the disease examined.

No other organism has been found constantly associated with the disease.

It closely follows the course of the disease. In the early stages, when the young leaves and tips of the shoots alone show symptoms, it is found in the inner layers of the living leaf-bud, on which it is unquestionably feeding, since it is able to grow and multiply. Later on, when the upper joints of the stem become affected, it is found chiefly congregated on the stem lesions. Still later, when the ear is developing, it is found at the base of the peduncle and in the flowers, which frequently fail to mature their grains.

It has not been found on rice plants not affected with ufra, including a large series of diseased plants from various parts of India with symptoms which appear to agree with those of the "brusone" disease of Italy, and also those attacked by *Piricularia Oryzæ*. It has not been found in the mud of paddy fields nor on plant débris in the water in infected fields (though there is evidence that it passes from plant to plant through the water at certain times of the year) but only on the growing plants, in an active state, or coiled up in a passive or resting condition within the glumes and under the sheaths after the plant has ceased to grow.

Inoculations with material which, so far as could be determined, contained no other constant organism but the worm, have been successful in producing typical ufra in localities where the disease is quite unknown.

The spread of the disease, both in these inoculations and in natural outbreaks, indicates that it is caused by a motile organism which can pass through the water and can ascend to the upper part of the plant. None of the other organisms found are likely to be able to do this without causing disease of the roots or base of the plant, which in ufra remain perfectly healthy after the top of the plant is affected. The worm does pass from plant to plant through the water and does climb up to reach the top of the shoot.

The reason why the injuries to the plant, found in ufra, are localised in certain parts, appears to be entirely connected with the anatomy of the plant. The cell walls of the epidermis and subjacent layers are strongly thickened and silicified throughout the stem, except near the growing point and for some distance above each node, where the walls remain thin and flexible, especially in the upper part of the stem.[1] The epidermis of both surfaces of the mature leaf blade is strongly silicified and provided with a cuticle of exceptional thickness and strength.[2] It is less thickened in the sheath, except along the median line of the outer surface, where it is further strengthened by a well-developed subepidermal layer of fibres. This fibrous layer diminishes as the margins of the sheath are approached. On the inner surface the fibrous layer is absent but the walls of the epidermis are thick near the median line and get progressively thinner as the margins are approached. It is due to this distribution of the more rigid elements that the sheath maintains its position closely embracing the stem.[3] When the young inflorescence is formed, at the apex of the shoot, most of its elements are unthickened; the worms are able to reach it before thickening sets in, as the bud layers are forced apart by its growth. Large numbers of worms have been found in the inflorescence at a very early stage (Plate II, fig. 2), though, as already stated, they cannot usually reach the growing point of the vegetative shoot. This would seem to be the reason why arrest of development of the shoot is rare before the inflorescence is formed. In general it may be said that the position of the lesions, and their nature, are such as would be expected to result from the attack of an organism which is unable to obtain access to any but superficial cells and can only attack these when they are without

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[1] Van Breda de Haan, J. De Rijstplant: I Eene anatomische beschrijving der rijstplant, Meded. uit. v. h. Depart. v. Landbouw, Java, XV, 1911, p. 30.

[2] *Ib.* pp. 44-5 and D'Ippolito, G. Studio anatomico sul riso. Staz. Sper. Agrarie Italiane, XXXVII, 1904, p. 340-3.

[3] Van Breda de Haan, J. *loc. cit.* p. 38.

specially thickened silicified walls. Most parasitic organisms enter more or less completely into the tissues and, though entry may only be possible where the superficial cells are weak, subsequent spread within the tissues beyond these limits usually occurs. Thus *Piricularia Oryzæ* can even spread through the nodes to reach the stem below them. The worm never enters the tissues but feeds by sucking at minute wounds caused by a slender spine which can be protruded from the mouth. It is probably unable to feed anywhere but where the outer cell walls are thin and the exact localisation of the lesions to these parts is in harmony with what we would expect to find, assuming it to be the cause of the disease. The leaf blade is usually unaffected, except when the damage to the tissues lower down leads to its withering. In the sheath the outer surface less frequently shows marks of early attack than the inner and the median portion of the sheath remains unaltered when the margins are brown and dried up. On the stem the lesions exactly correspond to the regions where the outer cell walls are soft.

4. Morphology of Tylenchus angustus n. sp.

In the adult worm the cuticle is transversely striate, the striæ being very fine, about 1·5μ apart. The anterior end is marked by a cap-like region, consisting of indistinct lips which bound the mouth orifice. The mouth is furnished with a slender spear, 9 or 10μ long, the base of which is swollen and 3-partite. This spear is normally retracted into the pharynx but can be protruded when feeding. Behind the spear the œsophagus is slender as far as the œsophageal bulb, the centre of which is about 55μ behind the anterior end (extremes 42 to 68μ). Behind the bulb the œsophagus is at first more slender than in front but gradually increases in diameter to the point where it terminates in the main gut, where it narrows again slightly. The main gut begins about 140μ from the anterior end, the exact point being extremely difficult to make out. The orifice of the ventral excretory duct is a little behind the commencement of the broader part of the œsophagus, or about 80 to 100μ from the anterior end.

The adult female (Plate II, fig. 4) measures about ·9 mm in length (extremes ·7 to 1·1 mm) by about ·019 mm broad at the thickest part (extremes 015 to ·022 mm). It is therefore very slender in comparison

PLATE II

Fig 1.

Fig 2.

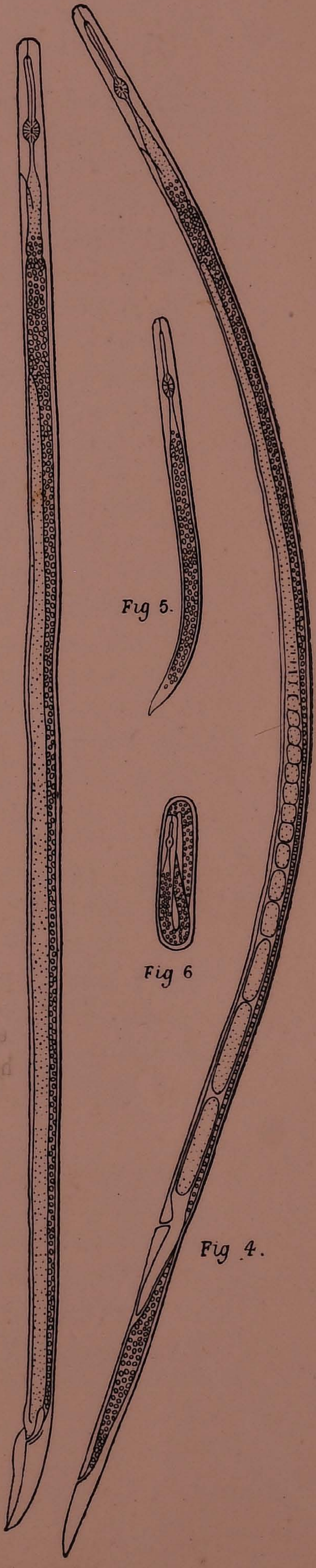

Fig 3.

Fig 4.

Fig 5.

Fig 6

TYLENCHUS ANGUSTUS

to its length, the length divided by the maximum breadth being about 50 (extremes 47 to 58). The breadth at the vulva is about eleven-twelfths of the maximum breadth, at the œsophageal bulb about four-fifths. The ovary is composed of a large anterior segment, extending forwards nearly to the beginning of the main gut, and a small rudimentary posterior segment. The vulva is situated seven to eight-tenths of the body length from the anterior end. The eggs (Plate II, fig. 6) are large, formed in a single row, and measure 80 to 88 by 16 to 20μ after laying. The anus is about 45μ from the posterior end and the tail tapers to a conical, slightly acute end.

The male (Plate II, fig. 3) is ·6 to 1·1 mm. long by ·014 to ·019 mm. broad and is therefore on the average slightly smaller than the female. The length divided by the breadth is about 44 (extremes 36 to 47). The alimentary canal and excretory duct agree in magnitude and relative position of the parts with the female. The spiculæ are about 42μ from the posterior end (extremes 34 to 48μ) and are slightly longer than the breadth of the body at this level. They have a short accessory piece. The bursa is narrow, tapering behind, and invisible in certain position of the worm; it does not quite reach the tip of the tail. The tail is more abruptly pointed than in the female, from the point of insertion of the anterior end of the bursa. No papillæ or glands were observed.

The first larval stage (Plate II, fig. 5) measures about 170 by 10μ after leaving the egg, and grows in a few days to 250 by 12μ. The number of moults is uncertain but there is one when the length is not much greater than 250μ and another when about 600μ, the latter giving rise to the mature forms. In shape there is nothing to distinguish the larvæ from the adults. The structure of the internal organs is difficult to make out, but the œsophagus appears to be proportionally longer than in the adult.

None of the other species of this genus, whose descriptions I have been able to obtain, agree in measurements and mode of life with the above, for which I propose the name *Tylenchus angustus*. One of the nearest is the well known *Tylenchus dipsaci* Kühn (*T. devastatrix*), which causes diseases of a number of cultivated plants (including rye, oats, wheat, potatoes, clover, lucerne, onions, etc.) in many countries but has not yet, apparently, been recorded in India. This species is, however,

considerably larger, as the following comparison indicates:—

	T. angustus.	T. dipsaci[1].
Length	·8 to 1·0 mm (extremes ·6 to 1·1 mm).	1·2 to 1·55 mm (extremes ·94 to 1·73 mm).
Length / Breadth	44 to 50 (extremes 36 to 58)	40 to 45 (extremes 31 to 51)
Length / Length of œsophagus . .	7 (?)	6
Length of spine . . .	9 to 10μ	12 to 15μ
Length / Length of tail . . .	20 (extremes 15 to 23)	16 to 17 (extremes 11 to 18)
Length / Length from vulva to posterior end	3·3 to 5	3·5 to 6·3 (average 5)

A still more important difference is in the mode of life of the two species. *T. dipsaci* is an endoparasite, living within the parenchyma of the stem and leaves of the infected plant; only as the plant ripens, or in severe attacks, as it withers, does the worm leave the tissues and seek the soil. In *T. angustus*, on the other hand, the tissues are never entered and the species is a true ectoparasite. As a consequence of this difference in behaviour, the hypertrophy of the tissues caused by *T. dipsaci* is not found in rice affected with ufra.

The other parasitic *Tylenchi* found on *Gramineæ* either occur in the roots only or, if on the above ground parts, cause characteristic galls. The present species has never been found on the roots, in spite of repeated searches, and never causes galls. Of interest is the species known as *T. oryzae* Br. de Haan, originally described as the cause of a serious rice disease called "omo mentek" in Java.[2] This species is found only in the roots and differs in its morphological characters from *T. angustus*. Recent investigations[3] show that it is not the true cause of

[1] Ritzema Bos quoted by K. Marcinowski, Parasitisch und semiparasitisch an Pflanzen lebende Nematoden. Arb. Kais. Biolog. Anst. f. Land-und Forst-wirtschaft, VII, 1910, p. 58.

[2] Breda de Hann, J. van. Een aaltjes-ziekte der rijst, "Omo mentek of Omo bambang". Meded. uit 'S Lands Plantentuin, LIII, 1902.

[3] Jaarboek v. h. Departement v. Landbouw in Nederlandsch-Indie, 1909, p. 75 and 1910, p. 107.

"omo mentek," as it has not been found possible to produce the disease by inoculating with it, and it has been obtained abundantly in the roots of healthy plants. The following comparison of the measurements of average females of the two species indicates the chief differences :—

	T. angustus.	T. oryzæ. (after Breda de Haan).
Length	0·9 mm	1·5 mm
$\frac{\text{Length}}{\text{Breadth}}$	50	35
Length of spine	9 to 10μ	19μ
$\frac{\text{Length}}{\text{Length of tail}}$	20	16
$\frac{\text{Length}}{\text{Length from vulva to posterior end}}$ . .	3·3 to 5	2·7
Eggs	80 to 88 by 16 to 20μ	102 by 26μ

5. Biology of Tylenchus angustus.

Adults, larval forms and eggs have been found together in all stages of the disease and this fact, joined to the failure to get the worm to develop away from the host plant, has prevented the life history from being completely followed out.

In the earliest cases of disease seen, in half-grown aman paddy in July, most of the individuals found in the inner layers of the bud were motile larval forms, but a few motile adults and some eggs were also present. In August adults were numerous. In October adults, larvæ and eggs were found and the same was the case at the end of November, all being still motile. In the Pusa inoculations there was a great multiplication of adults and larvæ (at least a hundredfold) between the beginning of September and the middle of November and at the latter date they were actively motile. In December motility had almost ceased in most of the cases examined. After December they remain immobile and dormant in the dry grains and stubble and probably recommence activity only with the flooding of the fields. It is not probable that activity begins sooner, as no record of the disease in seed-beds has been

obtained. In July the attack on aus paddy is well developed and the worms at this time of year are actively motile in water and capable of spreading freely from plant to plant. It may be assumed that multiplication only takes place between May or June and November, and many observations suggest that there are not less than three generations in this period. The number of eggs laid is not known. The female of *Tylenchus tritici* lays about 2,000; that of the present species probably lays considerably less; but supposing that only 100 are laid, one pair could, if all the larvæ reached maturity and were equally male and female, produce a quarter of a million individuals in three generations.

Up to the present *T. angustus* has only been found on rice. A wild grass (not identified) was reported in one instance to suffer from the same disease as the neighbouring paddy, but I have not been able to confirm this statement. On rice the worm has only been found on the above-ground parts, where its behaviour resembles that of the second larval stage of *T. tritici,* in that it tends to work its way under the leaf sheaths and round the edges of the inrolled leaf blades into the heart of the bud. A number of weeds growing in severely infected fields of aus paddy were examined without any trace of this species being found. So also I have failed to find it in the mud from the paddy fields, though from its small size and the difficulty of such a search its absence cannot be guaranteed.

Some experiments were made to test the vitality of *T. angustus* when dried in the laboratory and when immersed in water. *T. tritici* has been found to retain life in the dried condition for 27 years[1]; *T. dipsaci* for 2 years. Specimens of *T. angustus* dried on their host plant in blotting paper have been found mostly alive after 7 months: a few were still alive after 15 months. In the dormant condition they are coiled and are always found in this state at and after the time of harvest of the winter paddy, occurring chiefly within the glumes of the lower grains of the ear (but not within the grain itself if one has developed) and also under the upper leaf sheaths. Both adults and larval forms are capable of assuming this resting condition. They uncoil in water at once, but rarely show any motion after full extension has occurred. Sometimes they move languidly, in striking contrast to their active wriggling motion in the growing season. How far this difference in behaviour is dependent on external conditions is doubtful. It does not

[1] Bastian H. C. Monograph on the Anguillulidæ, Trans. Linn. Soc. xxv, 1866 (read 1864), p. 86.

seem to be a matter of temperature, as specimens collected at Narayanganj in October 1912 did not become active, but merely uncoiled, when placed in fresh water in an incubator at 90° F. in February 1913.[1] Besides they have been found normally active in Pusa in the middle of November but dormant in Noakhali in December, the temperature conditions being not markedly dissimilar in the two cases. It is difficult to reproduce all the natural conditions in the laboratory and further experiments are necessary to ascertain the cause of motility during the time when the crop is growing. It may be connected with the provision of fresh food and experiments to test this point are in progress.

Immersion in mud and water and in foul water leads to the death of the worms in from two to four months. In pure water they survive longer, several being still alive after four months, but either inactive or moving very languidly. No multiplication occurred as far as could be determined, either in the dried specimens or those immersed in water. The species is, I think, incapable of taking food from decomposing vegetable matter, but is a true parasite. Its behaviour in this respect was in marked contrast to that of several other species of nematodes found from time to time in decomposing paddy straw of old cases of ufra. These grew and multiplied freely in the absence of living plant tissue, and when immersed in water in which paddy straw was placed, and were evidently saprophytic. The commonest form was a species of *Diplogaster*.

Perhaps the most remarkable circumstance in connection with the disease is the comparative immunity of transplanted paddy of any kind to natural attack. Transplanted paddy is never, so far as I have seen or have been told, severely attacked. Indeed I am not certain that it is ever attacked at all but I think that it is so, mildly, in some cases. I could not find any such case in July and August 1912 and those that I saw in December 1911 were complicated by the attacks of aphids and borers. It is a most remarkable thing to see a plot of transplanted paddy perfectly healthy, surrounded by a large area only slightly lower in level, less than a foot in some cases, in which broadcasted paddy is severely diseased. Mr. Mason's statement that both dry land and wet flooded land suffer alike cannot be confirmed. It was probably due to the ryots mixing up the effects of drought, insects and *T. angustus* under the one name of ufra. The term appears to be applied to almost any blight

[1] Since the above was written it has been found that a limited number of these worms resumed active movements about the middle of April, when sown in water in the open laboratory.

in some places, even to red rot of sugarcane, and in the early stages of the enquiry it is certain that several diseases were confused. Only paddy growing in land which is submerged for a considerable time appears to be attacked by *T. angustus*. At first I was inclined to attribute this to some actual difference in the constitution of the two classes of paddy, either inherent or developed by the conditions under which they were grown. In particular the stress which has been laid by Italian and Japanese writers on the evil effects of insufficient aeration of the roots of paddy in predisposing to brusone suggested something of the same sort here. Broadcasted paddy occupies lower land, is under water for a longer period and the water has less chance of percolating and carrying down dissolved oxygen to the roots than in the case of the transplanted crop. The soil also is less thoroughly worked in the former than in the latter case. But the readiness with which transplanted plants succumbed when artificially inoculated at Dacca and Pusa has forced me to abandon this view. It was sufficient to place stalks bearing the *Tylenchus* in the water at the base of the plants to bring about a severe attack of ufra. The soil of the plot at Pusa was percolating freely and cannot have been really deficient in oxygen.

If the immunity of transplanted paddy is not connected with any peculiarity of the host plant, it must have reference to the behaviour of the parasite. Transplanted paddy is not exposed to as early infection as is the broadcasted crop. While in the seed-bed it does not appear to be liable to attack. After transplanting it can be artificially inoculated. It appears therefore as if under natural conditions the parasite does not usually reach the transplanted crop. Why this should be so is not clear and is one of the chief problems for future study.

6. Area affected and damage caused by ufra.

Owing to the backwardness of the affected tracts and the comparatively recent date of the organisation of the local Department of Agriculture, accurate information as to the extent of the area affected with ufra and the amount of damage caused is not yet available.

In Noakhali District the disease occurs throughout the central and western portions of the District, information of its existence in Sudharam, Begumganj, Ramganj and Lakhipur thanas having been obtained. In Begumganj thana the loss in 1910 was roughly estimated at 200,000 maunds of grain. Around Chaumuhani I was told that nearly half of

the winter paddy was lost in 1911. From my own observations I should think this was an under- rather than an over-estimate. The disease is said to have been known in this neighbourhood for about 30 years. It began to increase some 20 years ago and to cause serious damage more recently. Several middle aged men told me that it was unknown in their fathers' time and has much increased during the past six or eight years. This is perhaps as near as we can hope to get to its history.

In Tippera it is known to be prevalent near Chandpur, no doubt as a northward extension from Noakhali, and also around Comilla. The intervening area is probably more or less infected, especially as it is said to occur south of Laksam. The intensity of the disease is not known.

In Dacca, according to the District Gazetteer, considerable areas in the Madhupur jungle were destroyed in 1904 and 1905 "by a mysterious blight called "dak" which the villagers described as a vapour issuing from the ground but which appears to have been an obscure form of blight". Specimens of "dak" were first sent to Pusa in 1911 and proved to be identical with the ufra of Noakhali and Tippera. In 1912 deep water aman paddy was attacked by "dak" in the Narayangunj subdivision. The Mycological Collector of the Bengal Department of Agriculture, Babu A. L. Som, reported that the disease had been known for some ten years but had only become serious within the past five years. It was said not to attack the aus crop. His collections showed that the attack was a typical and very severe one. Another large outbreak has been reported quite recently around Bikrampur and is said to extend to the west and north-west for a considerable distance, towards the main stream of the Padma. It is certain that, as attention is directed to the pest by these enquiries, new localities will be revealed. It is not probable that these will represent areas of new infection. The evidence, so far, is that the disease spreads slowly and apparent new extensions will be, for the most part, merely the result for more careful enquiries for some time to come. It is hoped to arrange for a survey of the infected tracts during the coming year. Those who know the means of communication available in the districts mentioned during the paddy season, will appreciate the difficulties of this task.

7. Remedial measures.

It is obvious that the best methods to adopt in fighting this disease cannot be decided on in a few months. Experiments will have to be carried out within the affected area and, as in all crop experiments, may

have to be repeated for several years before reliable results are obtained. Still, as the need is pressing, there are several measures which can be advised for immediate practice and some of these have been already recommended and are being tested by the cultivators themselves.

All the possible measures to be considered may be divided into those directed against the parasite and intended to lead to a reduction in its numbers, and those whose object is to render the host plant less susceptible to damage.

Into the first group fall all attempts to kill the parasite. It is, I think, useless to try any direct attack on it, while it is actively swarming in the fields during the growth period of the plant. Spraying a crop like paddy in India may be at once dismissed as impracticable. The addition of some vermicide to the water on the fields might be feasible were it not that the majority of the worms are out of reach of the water in the inner layers of the bud and towards the top of the plant. The cost of dealing with any large area would also probably be prohibitive. During the cold weather months, when the worms are inactive in the stubble and grain, direct attack is more hopeful. Success at this period will depend on several factors. There is, first, the ability to destroy any large proportion of the worms in a given crop. Secondly, destruction must be carried out over a sufficiently large area to prevent reinfection. With a motile organism and large movements, tidal and gravitational, of the surface water, the chances of reinfection will probably be considerable. There is, thirdly, a possibility that the disease will be found in some localities in the boro paddy, a crop which grows during the only months when active measures are feasible. This is, perhaps, not an important difficulty, as boro paddy is not as yet known to get the disease and is besides confined to certain well-defined tracts. It need not, for instance, enter into calculation at all in Noakhali District.

I believe that it will be found possible to reduce the parasite considerably by burning all the stubble left after the harvest of the winter rice. It may be necessary to supplement this by securing worm-free seed and by some cultural treatment of the soil. A certain proportion of the worms undoubtedly pass the early part of the period after harvest in the stubble. Others equally certainly go to the grain heaps, through ears affected with "pucca" ufra. Whether any remain alive during this period in the soil is not yet certain. The evidence, so far as it goes, suggests that these last two lots of worms are not of great importance in renewing the disease. If the disease were commonly seed-borne,

extension would probably have been much more rapid than has been the case, as exchange of seed from one locality to another goes on to some extent. If it were soil-borne, the soil of transplanted paddy fields would certainly have been infected long ago, especially as it is the practice at the end of the cold weather to spread soil from the lowest land on to the fields intended for jute and from which a second crop of transplanted winter paddy will be taken. We know from inoculations that these plants will get the disease if the parasite reaches them and we may therefore conclude that it is not present about the time of transplanting.

Some encouraging reports of the beneficial effects of burning the stubble have already been received, the recommendation to do so having been made last year by both Mr. Fletcher and myself. The damage done by borers in the districts affected with ufra is such that Mr. Fletcher strongly advised burning the stubble as a regular agricultural routine. The practice is widespread in other parts of Bengal and should be introduced everywhere that ufra or serious damage by borers occurs.

Experiments on the effect of more thoroughly working the soil of the lower paddy fields than is customary are advisable, as even though the worm may not remain alive ordinarily in the soil, it is likely to be found in shed grain and fragments of stubble on the surface. By ploughing in these there is a prospect of their speedy decomposition and consequent death of the worm if, as the evidence suggests, it is unable to live long in moist soil. There are difficulties in the way, however, since much of the lower land gets very hard after harvest and has to be softened by the spring showers before the local cattle can plough it. Furthermore the peculiar nitrogen relations of rice are such that there is a danger of causing a serious loss of nitrogen or the accumulation of poisonous nitrites by over cultivation.[1]

Should it be found that the use of infected seed is more dangerous than at present appears to be the case, steps will have to be taken to ensure a supply of healthy seed. This will require some organisation but should not be beyond the power of the local Department to undertake.

Into the second group of prophylactic measures fall all efforts to improve the health of the plant and to grow it under conditions

[1] *Cf.* Kelly, W. P. The Assimilation of Nitrogen by rice. Hawaii Agric. Expt. Stat., Bull. No. 24, 1911; and G. Daikuhara and T. Imaseki. On the behaviour of Nitrate in Paddy Soils. Bull. Central Agric. Expt. Stat. Japan, I, No. 2, 1907, p. 7.

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which will render it less liable to infection. The practice of transplanting should be encouraged wherever possible, owing to the observed freedom from ufra of the transplanted crop. It will probably be objected that transplantation on a larger scale than at present is not possible owing to the nature of the annual inundation, but I am by no means satisfied that this is the case. The mere fact that the transplanted area near Begumganj has considerably increased in recent years, partly as a result of the extension of jute cultivation, is sufficient to disprove it. The people are already transplanting more than they did and would probably do so still more if urged. Transplanting is much more troublesome than broadcasting and the cultivators in Noakhali, as in certain other paddy tracts, are uncommonly lazy. I gathered that the increase in jute cultivation was not altogether independent of the efforts of the jute merchants ; in these matters influence counts for much and I think a good deal can be done towards increasing the transplanted area.

Liming the soil was tried, at the instance of the Bengal Department of Agriculture, in 1912. It appears to have had the effect of delaying the first appearance of the disease but not saving the crop. The cost is so high in Noakhali District as to make it doubtful if it can be used on a large scale.

The evidence, so far as it goes, appears to suggest that rice is more susceptible to ufra when it is grown under conditions which preclude the aeration of the soil throughout the greater part of the year. It is true that inoculations in fairly permeable soil succeeded at Pusa, but the attack was not so severe as is commonly met with in the submerged paddy fields near Begumganj. The growth of deep water broadcasted paddy in a great deal of this area cannot be avoided owing to the nature of the levels but something might be done to promote drainage over considerable areas. The improvement of natural drainage in lower Bengal has been prominently before Government for some time and any steps in this direction, in the districts affected with ufra, will probably help in reducing the losses caused by the disease.

A serious disease of rice is one of the greatest calamities that could befall the people in districts such as those referred to above (where nearly three-quarters of the cultivated area is under paddy), for no other food-crop can replace it. When, in addition, the disease is of a highly infectious nature, as the results of the inoculations show it to be in this case, the risk of spread to other areas is even a more important consideration than the losses caused within the infected area itself. On the one

side is the whole of the enormous paddy area of Bengal; on the other at a greater distance but joined by an almost continuous belt of paddy cultivation, is the Irrawaddy Delta, which supplies the bulk of the export rice of India. Were it certain that transplanted paddy would remain immune, the greater part of these areas might be regarded as not exposed to serious risk. But transplanted paddy has been artificially inoculated and it is not safe to rely on its apparent immunity. No reports of the disease having appeared west of the Brahmaputra have been received. The Irrawaddy Delta is also free from it, so far as I was able to determine during a recent tour in Burma, though several little known and comparatively unimportant rice diseases were found and will be further referred to below.

Rice is perhaps less subject to disease than any other important cereal. The appearance of a new disease, of such intensity that the crop in many fields in the infected districts has been found not worth harvesting is an occurrence that commands attention. In more advanced countries it is probable that a special staff would be deputed to secure an immediate thorough investigation. We have not yet reached the stage in India where this is possible and the available staff has many other calls on its energies. I hope, however, shortly to be in a position to clear up some of the points which still remain obscure in the life history of the parasite and the behaviour of the host plant to its attack. In collaboration with the Bengal Department we shall then be in a position to fight it on more rational lines and with better prospect of success. At present our recommendations are more or less tentative and we must await the results of the experiments which have been planned or are already in progress before undertaking the work on a scale commensurate with the importance of the subject.

In conclusion I must acknowledge, gratefully, the assistance which I have received from the officers of the Bengal Department of Agriculture in this enquiry, and in particular from Messrs. Hector and Birt, respectively Economic Botanist and late Deputy Director of that Department.

II.—SOME FUNGUS DISEASES OF RICE.

The following is a brief note on some diseases of rice observed in Burma in the course of a tour in November-December, 1912.

Rice bunt.

Tilletia horrida Tak.

This disease occurs throughout the lower part of the Irrawaddy Delta from Rangoon to Bassein but was nowhere found to be causing much damage. As a rule only scattered cases occur and it is not easily detected in the paddy fields without careful search.

The fungus was first described by Takahashi [1] in Japan, where Miyake (1910) states it is rare. Later on it was discovered in the United States,[2] where it did some damage to South Carolina rice. It is believed to have been imported from Japan, but seems to have been completely stamped out in a few years in South Carolina. In Louisiana it has also been reported but not usually in amounts to cause much loss. More recently it has been signalled in Indo China.[3] No other records of its occurrence appear to exist.

Towards the end of 1909, the Director of the Research Institute of the Royal Agricultural College, Berlin, reported that smut spores were constantly found in rice bran imported from Burma and Siam. Specimens of the bran were also sent and these enabled me to identify the fungus as *Tilletia horrida*.[4] A special search was therefore made for it during my recent tour and its existence in sufficient quantity to account for the presence of a few spores in almost every specimen of rice bran in Germany (which gets most of its rice from Burma and Siam) was confirmed. It is probable that the species is more widely distributed in South-Eastern Asia than appears from the scanty records.

The parasite is allied to that which causes the well known bunt of wheat, and though its life history has not been worked out, there is reason to believe from the results of the treatment adopted in South Carolina that it enters the young seedling while still below ground just as in wheat bunt. Nothing can be seen of it until it reaches the sporing stage, which only occurs when the grains are formed. Individual grains are

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[1] Takahashi, Y. On *Ustilago virens* Cooke and a new species of *Tilletia* parasitic on the rice plant. Tokyo Botanical Magazine, X, p. 16, 1896.

[2] Anderson, A. P. Rice Blast and a new smut on the rice plant. S. Carolina Agric. Expt. Stat., Bull. No. 41, 1899, and *Tilletia horrida* Tak. on Rice Plant in South Carolina. Bull. Torrey. Bot. Club, XXIX, 1902, p. 35.

[3] Duport, L. Notes sur quelques maladies et ennemies des Plantes cultivées en Extrême-Orient. Bull. Econ. de l' Indochine, XV, No. 99, 1912, p. 785.

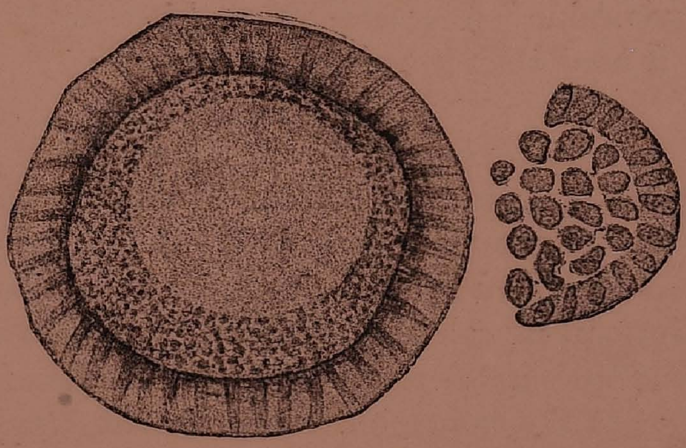
[4] Filter, P. Ueber das Vorkommen von *Tilletia horrida* Takahashi in Reisfuttermehlen. Centralbl. f. Bakter., 2nd. Ab., XXIX, 1911, p. 342.

then found wholly or partly changed to a black powdery mass, which is almost hidden by the enclosing unaffected glumes (Plate I, fig. 5). In South Carolina it is said that many heads bore as much as 25 per cent. of smutted grains. In India as a rule only two or three grains in an ear are affected.

The mycelium can be found within the stem tissues of affected plants. When it reaches the grains it develops chiefly under the thin membrane which forms the skin of the grain and consists of the wall of the ovary and the outer layers of the true seed. As this membrane is removed in milling and forms a considerable proportion of the rice bran which is exported, chiefly for cattle food, it can easily be understood that a comparatively small proportion of bunted grain will contaminate the bran sufficiently to explain the presence of *Tilletia* spores in practically every sample from Burma examined in Germany.

Frequently it is difficult to detect infected grains without breaking them. In other cases the glumes are forced a little apart and a black mass of spores is extruded. The spores are sticky and adhere to the surface of the glumes and even to the outside of healthy grains in contact with the affected ones. In the earlier stages they are enclosed in a thin membrane (the outer skin of the grain) but later on this usually ruptures and they lie free within the glumes. The spore mass may entirely replace the starch cells of the seed or may form only a layer of greater or less extent in the endosperm.

The individual spores are round or occasionally elliptical, opaque black when mature, light to dark brown when young. They measure usually from 20 to 24μ in diameter. The structure of the wall is peculiar (Text fig. 2), giving the impression, when seen with low powers



Text figure 2. Spore of Tilletia horrida in optical section and surface view + 1800.

of the microscope, of a dark band, furnished with projecting curved spines. Takahashi's figure shows this appearance. More carefully examined, however, the "spines" are found to be thickened blunt pegs formed in the substance of a thin hyaline membrane, which persists until after maturity. Seen in surface view the blunt ends of the thickenings appear dark, the spaces between being light, so that a reticular effect of light bands is given. The structure recalls that described and figured by Massee[1] in *Tilletia rugispora* Ellis. The hyaline membrane is somewhat gelatinous when moist and the adhesive properties of the spores are due to it.

Mixed with the spores are numerous large yellowish or sub-hyaline cells, which represent, in part, immature spores.

Attempts to germinate the spores failed. A similar failure has been reported from the United States and Germany. Takahashi has, however, observed their germination in Japan; after three days in water they put out a germ-tube (promycelium) septate at the tip and bearing at its end a cluster of 10 to 20 needle-shaped sporidia, 38 to 53μ in length and composed of 3 or 4 cells after falling from the promycelium.

The parasite belongs to a group which is often very destructive to cereals. They can, however, usually be checked by steeping the seed in certain fungicides. Oats and wheat are habitually treated in this way in many countries. Experiments in South Carolina showed that rice bunt may be almost entirely prevented by floating out and removing the light grain (which include the infected ones) in cold water and then soaking the seed for twenty-four hours in a solution of 1½ lbs. liver of sulphur in 25 gallons of water, or by employing a 2 per cent. solution and soaking the seed for only two hours. I saw no case where treatment was called for, but the members of this group of parasites have a way of multiplying rapidly under favourable circumstances and it is useful to know that an effective remedy is available, in case of necessity.

False smut.

Ustilaginoidea virens (Cke.) Tak.

This fungus was first described from Tinnevelly in 1878 by Cooke, who took it for a true smut and called it *Ustilago virens*. It was next met with in Japan and named *Tilletia Oryzæ* by Patouillard, in 1887. Some years later the German mycologist, Brefeld, grew it in culture and found from its behaviour and its close analogy to a similar fungus on *Setaria* that it belongs, not to the smuts, but to the *Ascomycetes* of the genus *Ustilaginoidea*. This view was accepted by Takahashi, who first pointed out

[1] Massee, G. A revision of the genus *Tilletia*. Kew Bulletin, 1899, p. 146, figs. 8 and 9

FALSE SMUT OF RICE.

the identity of the fungi described by Cooke and Patouillard, and by most other mycologists. It has been, however, disputed by Omori, who holds that *Ustilago virens* is a true smut but should be included in the genus *Sphacelotheca*, Brefeld's *Ustilaginoidea Oryzæ* being something quite different. The list of names has been further added to by Massee who described specimens sent by Watt from the Lushai Hills, Assam, as *Sphacelia Oryzæ*. Part of the original material from which these specimens were sent is in the Pusa Herbarium and shows that the fungus is Brefeld's *Ustilaginoidea*. In Mr. Massee's report to Sir G. Watt he states that "it has also been called *Ustilaginoidea Oryzæ* Brefeld," and why he gave it a new name is not clear.

All the above names undoubtedly refer to the same fungus. It is found throughout India, more especially on the shores of Bay of Bengal, in Malaya, Java, the Philippine Islands, China, Japan and the United States.

The parasite is visible only in the ears, where it develops its fructification in the ovary of individual grains. These are transformed into large velvety green masses, which may be more than twice the diameter of the normal grain (Plate III). The green colour is superficial, the inner parts of the swollen mass being orange-yellow near the surface and almost white in the centre. Only a few grains in each ear are usually affected and these may occupy any part of the ear. The glumes are unaltered and are found closely applied to the centre of the lower part of the green mass, which bursts out above and laterally from between them. Sometimes one or other of the glumes may be entirely encircled by the fungus.

The young ovary is invaded by the parasite at an early stage in its development and is transformed into a hard mass of closely united fine colourless hyphæ. This sclerotium-like body grows and bursts out laterally between the closely applied glumes. Here its outer layers develop spores of a brownish-green colour when ripe but orange in the mass when immature. As the ripe spores are progressively formed from the surface inwards, the velvety green colour of the outer part, changing to orange and then colourless further in, is readily understood. In very old fruits the colour of the whole sclerotium, except the innermost part, is deep greenish-brown or almost black, the centre being yellowish and spores being found to a considerable depth.

The centre of the sclerotium is composed of pseudo-parenchymatous fungus elements which entirely replace the tissues of the grain. Nearer the surface the hyphæ are septate, sparingly branched and arranged radially,

(Text fig. 3 *a*) while the exterior consists of a mass of loosely adhering

Text fig. 3—Ustilaginoidea virens. *a* part of sclerotium bearing spores. *b* ripe spores. *c* young spores. *d* almost mature spores. *e* Germination of the spores and formation of secondary conidia. *f* Budding conidial form obtained in culture. Figs *b*—*d* × 900, figs. *e*, *f* × 600.

spores. The spores are formed laterally or, rarely, terminally on the radial hyphæ (Text fig. 3 *c, d*). The youngest spores are almost colourless and are found on the hyphæ bounding the white centre of the sclerotium. Those further out, as well as the hyphæ on which they are borne, have a yellowish-colour, forming in mass the orange-yellow zone of the fructification. Still further out mature spores are found still attached to the hyphæ and now greenish-brown in colour. The outermost layer consists of these spores, with a few fragments of the sporiferous hyphæ, which are ultimately almost entirely used up in the building of the spores. The young spores are smooth or almost so but when mature they have a rough olive-green granular coating, soluble in ammonia, caustic potash, alcohol and mineral acids. The same substance coats the older hyphæ to a lesser degree.

The spores are borne on minute projections from the sides of the radial hyphæ, sometimes so close to one another as almost to hide the hyphæ from view. They are usually round and measure from 4 to 6μ in diameter. Occasionally elongated ones, 8 by 4μ, are formed.

The germination has been described by Brefeld, who succeeded in carrying his cultures as far as the production of new sclerotia, bearing ripe spores, similar to those with which he started. From these spores he obtained a second type of germination, by the formation of slender septate hyphæ which, after a short growth, formed clusters of tiny pear-shaped colourless spores at their tips. I have only succeeded in obtaining this type of germination (Text fig. 3 *e*) and in spite of repeated attempts have failed to get the rich sclerotium-bearing cultures described by Brefeld.

The further life history is unknown. Omori found a yeast-like type of sporidia, which he stated were formed directly on the germinating spores, without any intervention of a germ-tube, and multiplied by budding. On this account he considers the Japanese fungus to be a true smut and not an *Ustilaginoidea*. I have also obtained, on attempting to cultivate the pear-shaped conidia, a budding form, as figured in text fig. 3 *f*. I am not satisfied, however, that this was not an impurity, as it is scarcely possible to distinguish the conidia, measuring as they do only 2 or 3 μ in length, from those of other fungi commonly present in the outer layers of the sclerotia.

Attempts to reproduce the disease at Pusa, whether by mixing the spores with the grain at the time of sowing, or by directly inoculating the just-opened flowers on the ear, have failed.

In this absence of knowledge of the full life history of the parasite, it is not possible to give satisfactory recommendations for treatment. Fortunately the disease is not severe in any part of India, so far as I can ascertain. It is more common than bunt, but still only affects a small percentage of the ears and usually only a few grains on each ear. Even if a treatment were known, I have seen no case where it would have been worth troubling to carry out.

Sterility.

(*Sclerotium Oryzæ* Catt. in part.)

Complaints have been made from time to time by the Milling industry, the Agricultural Department and in Settlement reports, of an undue proportion of light or sterile ears in Burmese rice. The condition appears to be familiar to the cultivators under the name of "gwa-bo" and, as it was feared that it might be identical with ufra, its investigation was the principal object of my tour in Burma.

The commonest condition found in "gwa-bo" was that in which the whole ear with its stalk for a variable distance was found withered, pale in colour, light and with all or nearly all the grains empty. This was found to be due to the attack of a boring grub in the stem, usually in the upper internodes. I was informed by Mr. Shroff, Entomological Assistant to the Burma Department of Agriculture, that this insect is probably *Schoenobius bipunctifer*. One variety of attack is caused by the same or a different grub eating transversely round the inside of the stem, so as to cause a "ringing" wound, visible from the outside as a discoloured band. If the attack is late some of the grains may set and a partially sterile ear results.

In other cases the ear was found less completely sterile, with many half-formed grains, the grains being brown in colour or spotted brown and straw coloured. Most of these cases were due to the attack of a larger borer in one of the lowest internodes near the ground level. This, Mr. Shroff said, was possibly *Nonagria*. Plants thus attacked seem able to produce ears but not to mature any but a limited number of grains.

In a third set of cases the stem was sound but individual grains had been punctured and sucked or eaten out. This form of insect attack, while not causing such obvious damage as the stem borers, must yet be responsible for a considerable loss of grain.

In almost all these cases, the affected ears were invaded by saprophytic and weakly parasitic moulds.[1] Still it may safely be said that the bulk of the damage known as "gwa-bo" in Lower Burma is caused by insect pests of paddy.

In Upper Burma the same insect pests were found, but, in addition, a considerable number of cases were encountered in which no trace of insect injury could be detected but which nevertheless had an undue proportion of light or empty grains. The ears in these cases were not discoloured in any way, the glumes of the light grains were normal and, except in late cases, moulds were not present within them to any appreciable extent. In fact considerable difficulty was experienced in deciding, without examination of the individual grains, whether any particular plant was bearing normally or was partially sterile, until it was noticed that this form of sterility was invariably accompanied by excessive late tillering and the development of green sterile shoots from the basal nodes of the stalks. As the crop was nearly ripe it was easy to pick out such plants as bore these green shoots and in every case it was found that the ears were not maturing a full proportion of their grain. It was further noticed that when one plant in a clump bore these late shoots, all the other plants in that clump were as a rule similarly affected and every ear had a considerable number, often up to 50 per cent. or more, of light grains.

An examination of these plants showed that the base of the stem was usually discoloured at the lowest distinct internode or the next one or two above. At this point fungus hyphæ were found penetrating the stem tissues and also, sometimes in considerable quantity, in the cavity of the pith.

The lower leaf sheaths were also found invaded by similar hyphæ and were rotten and crumbled to shreds readily. Within the pith cavity, and also in greater amount in the rotting sheaths, large numbers of minute, round, shiny, sclerotia were found, embedded in and obviously arising from the hyphæ.

Specimens bearing these sclerotia were sent to Pusa, where their examination was taken up by Mr. Shaw, Supernumerary Mycologist. He

[1] The following is a list of the fungi found commonly on the ears, stalks or leaves of rice in Lower Burma but not in any case doing material damage, being chiefly present on plants already weakened by insect attack. *Cercospora Oryzæ* Miyake, (?) *Entyloma* sp., *Epicoccum hyalopes* Miyake, *Fusarium* sp., *Metasphæria albescens* v. Thuem., *Nectria Bolbophylli* P. Henn., *Phoma glumarum* Ell. and Trac., *Pyrenochæte Oryzæ* Shirai, *Septoria* sp.

found that the fungus was *Sclerotium Oryzæ* Catt.; a rice parasite first described in Italy in 1879, but concerning the life history and parasitism of which not much is known. An account of Mr. Shaw's work with this fungus, which proves to be a virulent parasite, is now in the press.

Subsequent enquiry showed that the same fungus is commonly present in rice fields in the neighbourhood of Samalkota, in Madras Presidency, and it has also been found since at Pusa, always causing the symptoms mentioned above. This hitherto unsuspected disease of rice is, therefore, widely distributed in India. The amount of damage caused by it is, as yet, unknown. In Burma it does not appear to be responsible for any but a small part of the losses caused by "gwa-bo." Outside India it is known in Japan and Italy. It is not unlikely to occur elsewhere and to have been overlooked, since as already stated it is difficult of detection. In the United States a disease known as "rice blight" has been described[1], but without ascertaining the cause. From the description it would seem possible that *Sclerotium Oryzæ* is responsible.

No remedial measures can be suggested without previous experimental work. Fortunately there is little evidence available that the disease occurs on a large enough scale in India to make treatment profitable.

[1] Hewitt, J. Lee. Rice blight. Arkansas Agric. Expt. Stat. Bull. No. 110, 1912.

DESCRIPTION OF THE PLATES.

PLATE I.

Fig. 1.—Ufra of rice. Advanced stage of "pucca" ufra, showing the thinning of the stem above the top node and the discolouration at the base of the ear. Most of the grains are light. Specimen from Narayanganj. $\frac{5}{6}$ natural size.

„ 2.—Ditto from a Pusa inoculation. The stem lesion is less marked than in fig. 1 and the base of the ear is not affected. $\frac{5}{6}$ natural size.

„ 3.—Ditto from a Pusa inoculation, with sheath still in place, showing the characteristic symptoms of "pucca" ufra. $\frac{5}{6}$ natural size.

„ 4.—Ditto. A typical case of "thor" ufra of aus paddy from Begumganj. Natural size.

„ 5.—Bunt of rice, *Tilletia horrida*, showing the spore masses exuded from between the glumes of affected grains. Natural size.

PLATE II.

Fig. 1.—Microphotograph of adult male of *Tylenchus angustus*.

„ 2.—Microphotograph of the young inflorescence, showing *T. angustus* congregated at this part of the plant.

„ 3.—Adult male of *T. angustus* X 225.

„ 4.—Adult female of *T. angustus* X 225.

„ 5.—Early larval stage of *T. angustus* X 225.

„ 6.—Egg with embryo of *T. angustus* X 460.

PLATE III.

Ustilaginoidea virens (Cke.) Tak

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